Claims

[c1] The Natural Index Contrast (NIC) method is a novel and attractive method to produce planar waveguides using nano materials such as dendrimer, nano silica, spin-on glass, and their compositions. This method can also be implemented with other suitable materials such as composition of dendrimer alone, composition of nano-silica alone, composition of spin-on glass alone, and any other material group where a natural refractive index contrast will exist in the suitable range for guiding optical signal of wavelengths ranging from 1060 nm to 1600 nm.

[c2] The NIC method as in claim 1 that simplifies waveguide core and cladding formation compared to other contemporary methods such as ion exchange, flame hydrolysis deposition, chemical vapor deposition, and thermal diffusion.

[c3] Dendrimer is a nanoscale polymeric material with 3-dimensional monodispersed molecular architechture that can be used for photonic waveguide and photonic integrated circuit fabrication.

[c4] Smooth, uniform, multi-molecule-layer films are formed by spin casting or spray deposition of dendrimer or other nano-material solution on to silicon, glass, quartz, and flexible substrates. This film is cured at a temperature and environment determined by the composition of the material and/or material substrate combination, for further processing via wet and/or dry etching

methods.

[c5] The said film of claim 4 wherein the film is suitable for forming waveguide core and cladding for guiding light in the infrared region of wavelengths 1060 nm to 1600 nm.

[c6] The said film of claim 4 wherein the film thickness can be controlled by (i) dendrimer generation; (ii) dendrimer solution concentration, pH, and viscosity; and (iii) spin-coating parameters such as ramp rate, spinning speed, and spinning duration.

[c7] Dendrimer films as in claim 4 wherein the refractive index can be modified by dendrimer's generation, chemical and/or heat treatment of the film, and by certain additives such as nano-silica, spin-on glass, and different generation of dendrimer.

[c8] The said film of claim 4 wherein the optical and dielectric properties can be tailored by doping dendrimer with rare-earth metals via solution phase chemistry such as chelation.

[c9] The said film of claim 4 wherein its optical properties have been modified via doping with fluorescing rare-earth metals; this film can be used for optical amplification in the wavelength range determined by the specific rare-earth metal and external pump combination.

[c10] The said film of claim 4 wherein its dielectric properties can be

modified via doping dendrimer or other said nanomaterials with high dielectric constant additives such as $CdGeAs_2$, $TlAsS_3$, Ag_3AsS_3, GeSe, $SrTiO_3$; the resulting film can be used for optical modulation where the modulation depth and frequency are determined by loading of specific additives and external electrical excitation combination.

[c11] The said film as in claim 4 wherein claims 5 through 10 can be satisfied by other nano-materials such as nano-silica and spin-on glass.

[c12] A method of fabricating NIC based planar waveguide utilizing the films as in claims 4 through 11 and that involve the following steps:

a. Providing a suitable substrate such as silicon having a refractive index in the range of 3.4–3.5. However, other substrate materials with different refractive index such as borosilicate glass, aluminosilicate glass, quartz, and low-temperature flexible substrate materials such as polyimide and Plexiglas can also be used.

b. Deposit a thin film of nanomaterial as in claims 4–11 (material A) on the said substrate. This film is designated the base layer having a refractive index in the range 1.4–1.5 that screens the substrate from waveguide zones. Under certain circumstances as determined by the practitionars routinely engaged in this art, extra coats, known as adhesion layer, may be added.

c. Deposit a second film of nanomaterial (material **B**) on top of the base layer. The second film is composed of a nanomaterial such as dendrimer having a refractive index slightly higher than the base film (e.g., 1.41 and above), but at least 1% higher than the base film, to establish a NIC value suitable for guiding the wavelength of choice.

d. The second film is patterned by an etching process such as reactive ion etching (RIE) to form sharp walled ridges that forms the waveguide core. Typical core dimension can be between $x \times y$ μm^2, where x and y can range between 2 and 8 μm. Prior to etching, a mask is laid on the film. The mask is pre-written with the desired patterns and common photolithography with photo-resist steps is followed to develop the patterns on the film. Common mask aligner and stripping method can be used prior to reactive ion etching. Any number of ridges and slabs can be patterned from a single mask depending on a given design.

e. After the etching process is completed, another zone of material **A** is deposited on top of the core obtained via above mentioned procedure (d). This zone fills-in the intra-core gaps created by the etching process and builds a layer on top of it that burries the core completely. This zone of material **A** along with the base layer encloses the core completely thus forming the waveguide cladding.

f. Finally, a film is deposited on top of the whole structure called the cover. This is either a polymeric material such as poly

siloxane or a glassy material such as spin-on glass or nano-silica plus silane whose refractive index is unspecified.

[c13] The said waveguide is capable of transmitting light in the wavelength range 1060 nm to 1600 nm. The said waveguide forms the basic element for construction of photonic integrated circuits such as arrayed waveguide grating (AWG), reflective arrayed waveguide grating (RAWG), interleaver, interferometer, splitter, coupler, optical add/drop multiplexer, channel monitor, gain equalizer, tunable attenuator, and other devices operating on waveguiding principle.

[c14] The said method of claim 12 wherein different designs and masks can be used to fabricate other devices via triple-phase integration described in the text. Examples include optical amplifier, wavelength router, sensor, optical modulator, transmitter, receiver, transponder, and fully built dense wavelength division multiplexer and demultiplxer.

[c15] The said method of claim 12 wherein different designs and masks can be used to fabricate waveguide interconnects to monolithically integrate multiple photonic functionalities on a single chip, and for optical data links.

[c16] A method of an optical waveguide amplifier fabrication; wherein a waveguide as in claim 4 through 11; the said amplifier is composed of:

a. A substrate as in claim 12.

b. A single or plurality of waveguides fabricated via method as in claim 12.

c. A waveguide amplifying zone fabricated simultaneously following steps as in claim 12.

d. The said amplifying zone contains waveguiding nanomaterials doped with one or more of rare-earth metal ions such as Er^{3+}, Pr^{3+}, Nd^{3+}, Th^{3+}, Ho^{3+}, Tb^{3+}, Eu^{3+}, and/or other additives.

e. A pump coupling zone fabricated simultaneously following steps as in claim 12; and

f. The input ports, output ports, and amplifying zone(s) fabricated monilothically and are connected via waveguide interconnect on the said substrate.

[c17] The said amplifier of claim 16 can be pumped via an external laser in the appropriate absorption wavelength range, determined by the dopant metals, either via external coupling with the help of a WDM coupler or via integrated design on the same substrate without requiring a WDM coupler.

[c18] The amplification efficiency or amplification per unit length of the waveguide amplifier of claim 16 can be tuned by the loading (ppm) of the fluorescing metal in dendrimer. A wide range of loading is possible via solution phase chemistry such as chelating, from a few ppm to more than 1000 ppm.

[c19] The total amplification of the said waveguide amplifier of claim 16 can be controlled by the length of the waveguide, its core dimension, power and wavelength of the pump laser, efficiency of amplification per claim 18, and signal wavelength of interest.